BLOCKING HIGHS OVER THE EASTERN NORTH ATLANTIC OCEAN AND WESTERN EUROPE

R. A. SANDERS

U. S. Weather Bureau Forecast Center, Washington National Airport, Washington, D. C.[1]

[Manuscript received March 31, 1952; revised manuscript received January 19, 1953]

ABSTRACT

The concept of blocking is briefly reviewed and a definition of "blocking High" in terms applicable to the daily sea level weather map of the eastern North Atlantic Ocean is adopted. The monthly frequency and geographical distribution of blocking Highs as defined are determined from forty years of Historical Weather Maps. Several features of these distributions are discussed in relation to observed monthly weather variations.

INTRODUCTION

The major synoptic features of the weather over the North Atlantic Ocean are often described in terms of their close connection with either the Icelandic Low or the Azores High. An essential attribute of the dominance of these systems in the synoptic picture that is usually visualized is the concept of a broad band of "prevailing westerlies" separating the two. At the outset of this discussion it is important to recognize, however, that such features are most prominently displayed on mean charts and that in day-to-day weather maps this simplified picture is more often than not considerably complicated, particularly by the presence of large stationary Highs in the region where the prevailing westerlies are normally located. These surface Highs, which are the subject of study in this report, can thus be considered as impeding the usual westerly flow and as forming a "block" around which other pressure systems such as troughs and cyclones must detour. Because of the important part these Highs play in the mechanism referred to as "blocking," it will be helpful to review briefly the principal features of the mechanism.

DISCUSSION OF THE BLOCKING MECHANISM

Namias and Clapp [1], Elliott and Smith [2], and Rex [3] have pointed out that the phenomenon of blocking is associated with the retrogression or slowing down in the normal eastward movement of ridges, troughs, Lows, etc. The definitions for the purpose of identifying such a phenomenon are varied to meet the needs of the investigators writing on the subject and in accordance with the scope of their studies. Namias and Clapp conclude, "Blocking operates in the form of a progressively westward decline in the speed of the zonal circulation at 10,000 feet." Or, in a later work [4] in discussing the index cycle, Namias says, "Since an exchange of air between pole and equator is an obvious necessity for atmospheric heat balance, it would appear that those blocking waves which occur simultaneously with a great reservoir of cold polar air are the ones which materialize into an index cycle."

Elliott and Smith [2] have stated this idea from another point of view: "An explanation for the dynamical development consisting of the abnormal extension of the subtropical high cell into the region normally occupied by westerly flow involves the accumulation of heat in the region of the subtropical cell." Later they say, "The blocking process is postulated as the mechanism by which the circulation adjusts itself in order to redistribute this heat." Both viewpoints recognize blocking action as a process for distributing abnormal heat loads between zones.

Rex [3] related blocking to a splitting of the jet stream. After setting limits as to time and geography, he recorded cases to show how blocking occurs when this split in the westerlies exists at 500 mb. Rex, in reviewing some theoretical work by Rossby [5], further postulated that the initiation of a block is impossible downstream from any region in which subcritical velocities exist. The critical velocity depends on the change in the Coriolis force to the north, and the square of the half-width of the stream. Rex further stated that blocking will be initiated when a "sufficiently intense" cyclonic impulse is imparted to the system.

Meteorologists familiar with the analysis of synoptic charts and the issuing of forecasts for the North Atlantic recognize several characteristics of possible importance in the blocking mechanism. Some of these are as follows:

1. The movements of blocking Highs are relatively slow from day to day.
2. Once a large blocking High is established, it persists and when it finally begins to break, the pressure falls off slowly each day. This slow process, if identified early enough, might then give the forecaster a valuable clue as to the persistence of the weather regime.
3. Lows, on approaching a blocking High, either become stationary or are steered around the periphery of the High.

[1] Present address: Weather Bureau Airport Station, Kansas City, Mo.

From the preceding discussion there seems to be some need of more knowledge concerning the part blocking Highs play in the general circulation. The purpose of the present investigation is to determine the frequency and geographical distributions of blocking Highs over the eastern North Atlantic and western Europe and through a discussion of the results to study the characteristics of blocking throughout the seasons.

However, in order that these as well as other aspects of this problem can be investigated, it becomes necessary to provide some sort of objective definition of blocking, avoiding where possible time-consuming derived and computed observations, and at the same time attempting to suit the special requirements of a forecast office that deals with the day-to-day problem of forecasting the weather over the North Atlantic.

DEFINITION OF BLOCKING

The Daily Synoptic Series, Historical Weather Maps (Northern Hemisphere, Sea Level) was examined chart by chart for the period 1899–1938. If within the area bounded by latitudes 40° and 65° N. and between longitudes zero and 30° W. any isobar on the western lobe of a High (see *a* in fig. 1) moved west (in fig. 1 to *a'*) or remained in the same position on the following day, then by definition an instance of blocking was said to exist, the associated High was identified as a blocking High, and its position [2] and central pressure were recorded. Thus, for the hypothetical instance shown in figure 1, the position recorded would be 58° N., 14° E.

The results of recording the blocking Highs, as defined, for the period 1899–1938 are presented and discussed in the following sections.

MONTHLY MEAN PRESSURE AND FREQUENCY OF THE BLOCKING HIGHS

The average central pressure of the blocking High by months is shown in figure 2a. Each month represents an average of 275 cases. The smoothness of this annual curve with its single maximum in January and the single minimum in August is interesting when compared with the elevation of the sun through the year. The lag of the minimum following the summer solstice is longer than that of the January maximum following the winter solstice. However, the meaning or value of this curve may be questioned when it is noted later in the report that the frequency of blocking Highs centered over the land as compared with those over the ocean varies with the seasons.

Figure 2b shows in the mean the percentage of days on which blocking Highs occurred in each month. Unlike the single wave of figure 2a, this curve shows four waves

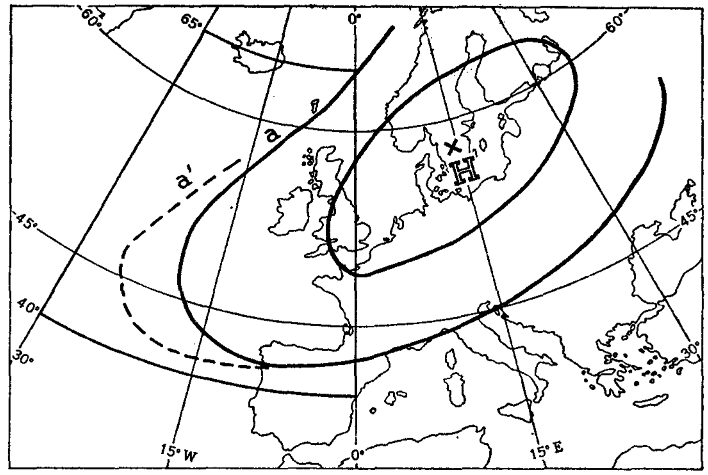

FIGURE 1.—Illustration of the 24-hour displacement (*a* to *a'*) of an isobar in the western lobe of a High, thereby defining a blocking High at the position marked X. The area between 40° and 65° N., and 0° and 30° W. is the region examined for such westward displacements in order to define blocking cases for the purposes of this study.

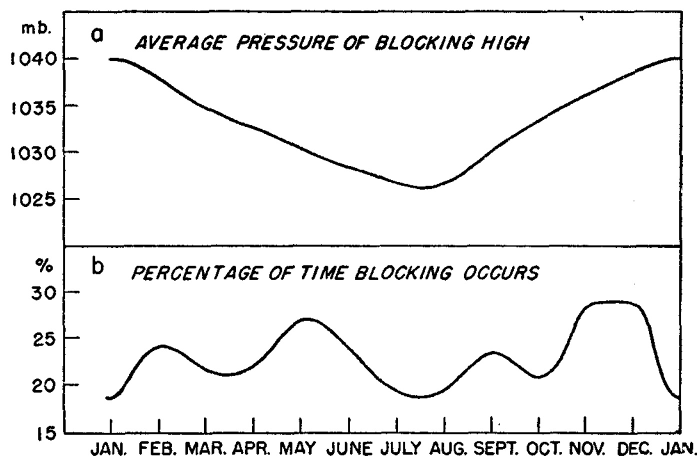

FIGURE 2—(a) Annual variation of average central pressure of blocking Highs (1899–1938), (b) Annual variation of percentage frequency of blocking Highs.

for the year, with a major maximum in November and December followed by maxima in February, May, and September. The time intervals between maxima are 2½, 3, 4, and 2½ months. This shows an increase in conditions associated with blocking in the late fall and early winter, while from December through summer to September there is an average decay. This suggests a sort of "condenser action" on an annual scale similar to that which Namias [4] has suggested happens at the beginning of an index cycle.

The low percentage of days with blocking Highs in January as compared with December may seem odd to those who watch Atlantic weather. A re-check of this month however, shows that blocking does occur, but more often is displaced to the east and does not affect the area under consideration. January circulation as shown by the normal sea level chart [6] is characterized by strong

[2] In a few cases a High was located west of the specified area (e. g., west of Greenland), but there was a ridge which extended southeastward into the area and which then moved westward. These Highs also were recorded as blocking Highs. Examples of these may be found by inspection of synoptic charts for May 11, 1909 and May 29, 1936.

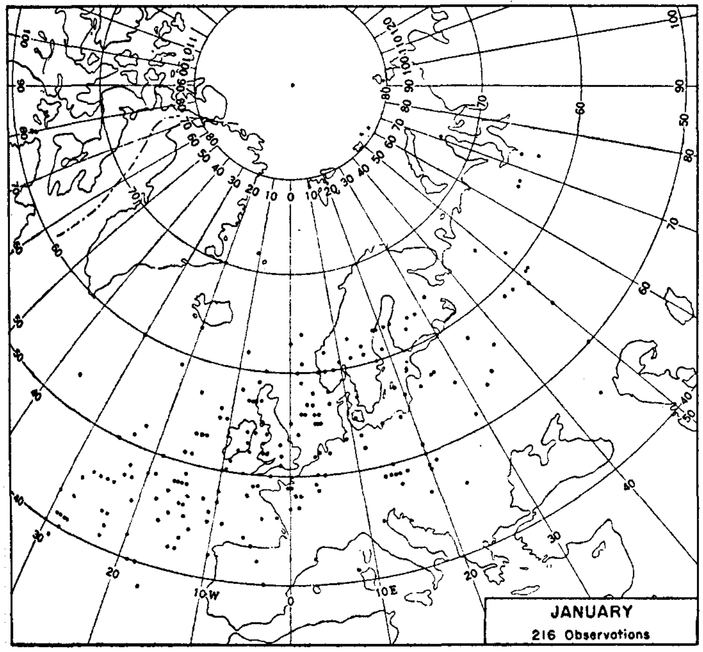

FIGURE 3.—Positions of the 216 blocking Highs observed on daily maps, January 1899–1938.

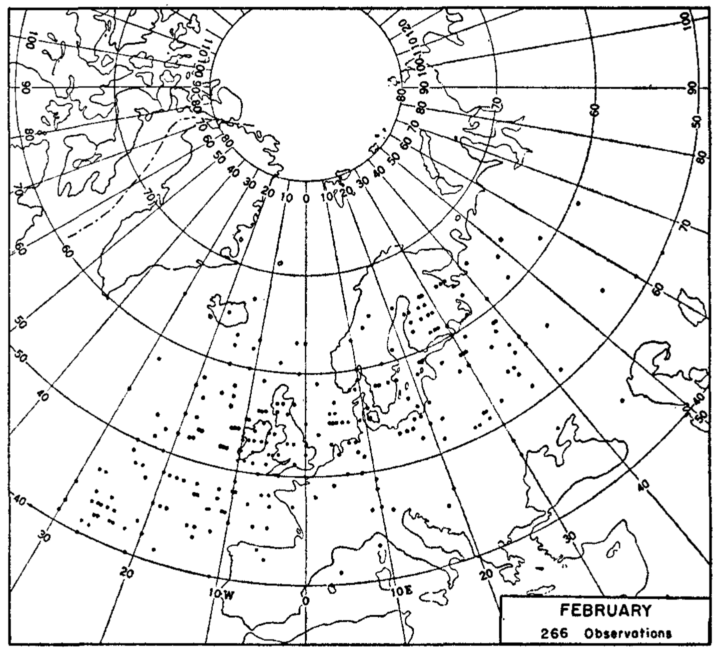

FIGURE 4.—Positions of the 266 blocking Highs observed on daily maps, February 1899–1938.

westerly flow across the Atlantic and cyclonic activity is at its height for the year.

GEOGRAPHICAL DISTRIBUTION OF BLOCKING HIGHS BY MONTHS

Figures 3 through 14 show the central positions of the blocking Highs as located in accordance with the definition of blocking mentioned earlier.

January (fig. 3)—The centers of the 216 blocking Highs lie on a band extending from the Azores to England, and to the North Sea, thence spreading over eastern Europe and western Asia. There are very few cases in the vicinity of Iceland as the Icelandic Low is strongest in this month. Though January on the average has a low number of cases of blocking, some years did have a high number; e. g., January 1907, 1917, 1929, and 1935. During these years the mean monthly temperatures were below normal for the British Isles, the Low Countries, Norway, and Sweden and above normal for Iceland [8]. This same pattern was true in February 1909, 1921, 1929, and 1932 when a high percentage of blocking days during the month existed along with below normal temperatures for eastern and southern Europe, near normal for the British Isles and Norway, and above normal for Iceland.

The cold flow from the east becomes a conservative part of the weather map when once established. In the January months, when there are only a few days of blocking, the temperatures are higher than normal on the Continent and generally colder in Iceland. In the latter case the westerly component would of course be stronger.

February (fig. 4)—The axis of points moves slightly northward during February, extending from near the Azores as an anchor point northeast to Ireland, then east over the North Sea to Poland and Finland. There are more cases in February (266) than in January (216), noteworthy increases occurring over the Baltic and near Ireland. The mean temperatures are lower in February at Leningrad and Helsinki than in any other month [8] and blocking seems to be associated with this cold spot. At the same time the westerlies over the Atlantic diminish, particularly in the north central part of the Atlantic. [6]. The Highs over eastern Europe retrograde and blocking becomes more frequent around Ireland and nearby waters. Namias' [4] description of the index cycle also shows that the major polar outbreak of the year occurs in February attended by blocking and pronounced meridional flow.

March (fig. 5)—Blocking diminishes in March (260 cases) and there is no definite band of blocking Highs as in January. The positions are removed farther to the north, into the Norwegian Sea and eastward into Finland. There are fewer cases over continental Europe, particularly France and Germany. In the months that do have a high number of blocking Highs there is no good relation to mean temperatures as was the case in January and February.

April (fig. 6)—By April, blocking has almost ceased on the Continent except in the Gulf of Bothnia area and is now confined to the waters from the Azores northward off Ireland and into the Norwegian Sea. Altogether there are 257 cases. A few are as far north as the Arctic;

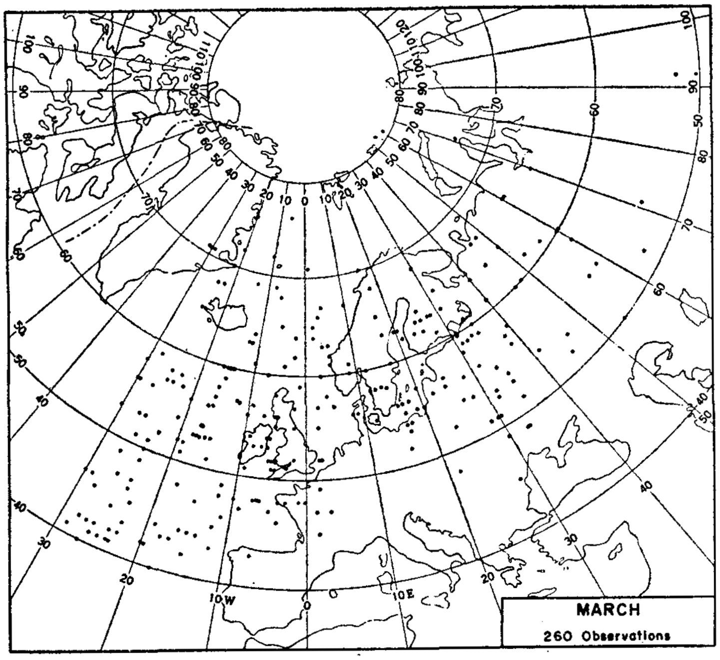

FIGURE 5.—Positions of the 260 blocking Highs observed on daily maps, March 1899–1938.

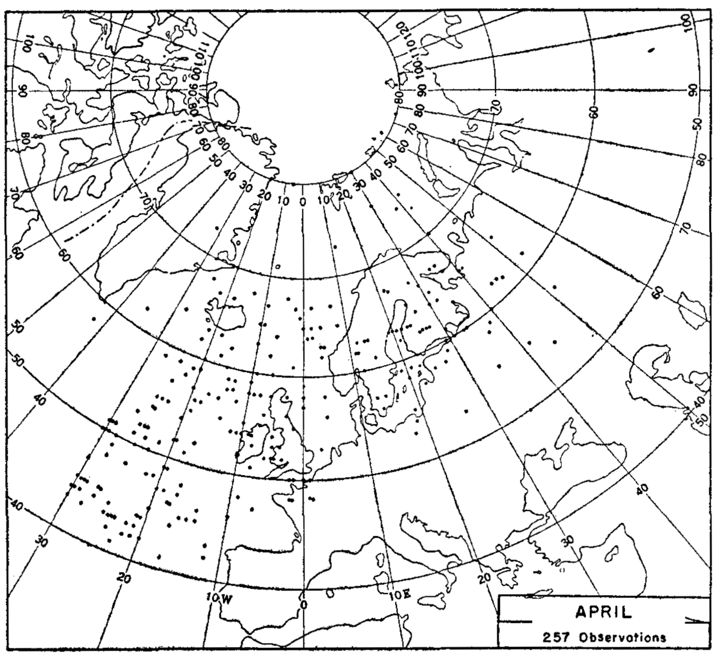

FIGURE 6.—Positions of the 257 blocking Highs observed on daily maps, April 1899–1938.

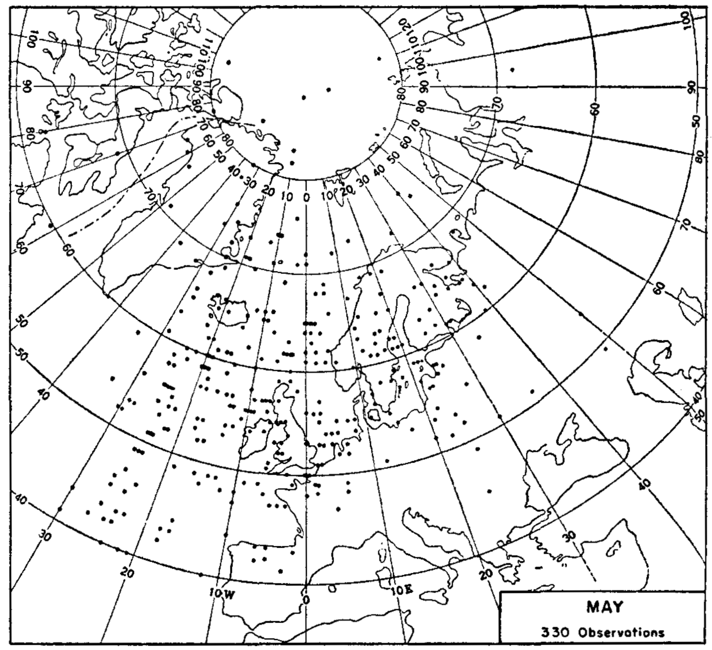

FIGURE 7.—Positions of the 330 blocking Highs observed on daily maps, May 1899–1938.

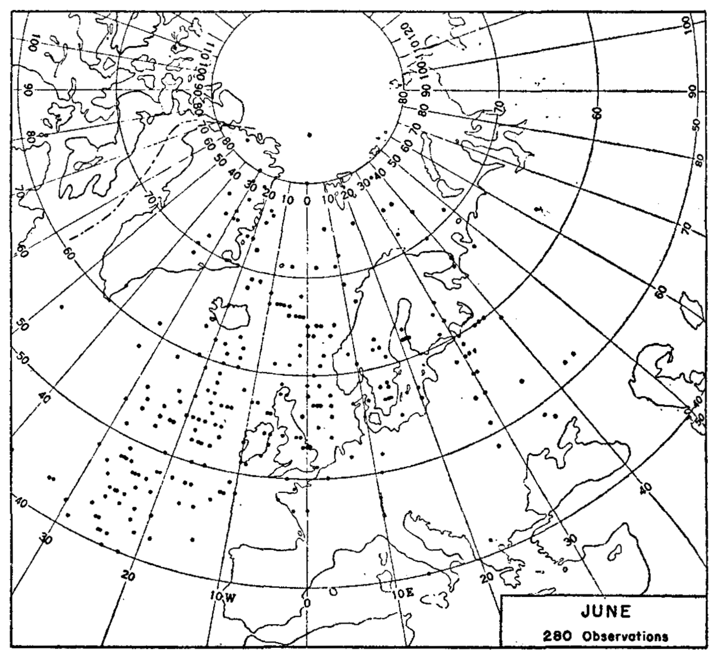

FIGURE 8.—Positions of the 280 blocking Highs observed on daily maps, June 1899–1938.

these are the polar Highs with ridges that extend southward into the area.

May (*fig. 7*)—From January to May the axis of blocking has swung from the Continent to the ocean and now shows a concentration of cases off Ireland and northeast into the Norwegian Sea. It is in this month that blocking becomes quite pronounced (330 cases). (See fig. 2b.) The Normal Weather Charts [6] shows that the 700-mb. flow in May is weaker over the area of our study than in any other month. In May, over the ocean and in western Europe, temperature gradients are weak, as shown on mean charts [6], thus permitting little modification of air masses from below. This will allow large pools of stable air to form at the 700-mb. level and below, and any upper level trough that passes through the area will likely be damped by this large body of stable surface air. In the months when there was a high percentage of blocking cases, the temperatures remained about normal over Europe except for higher values in the far north in northern Norway and Sweden [8].

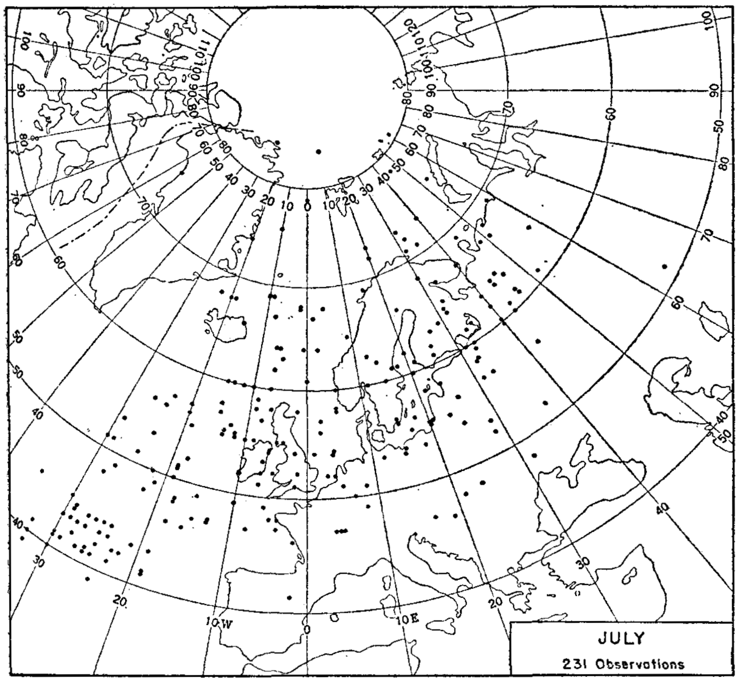

FIGURE 9.—Positions of the 231 blocking Highs observed on daily maps, July 1899–1938.

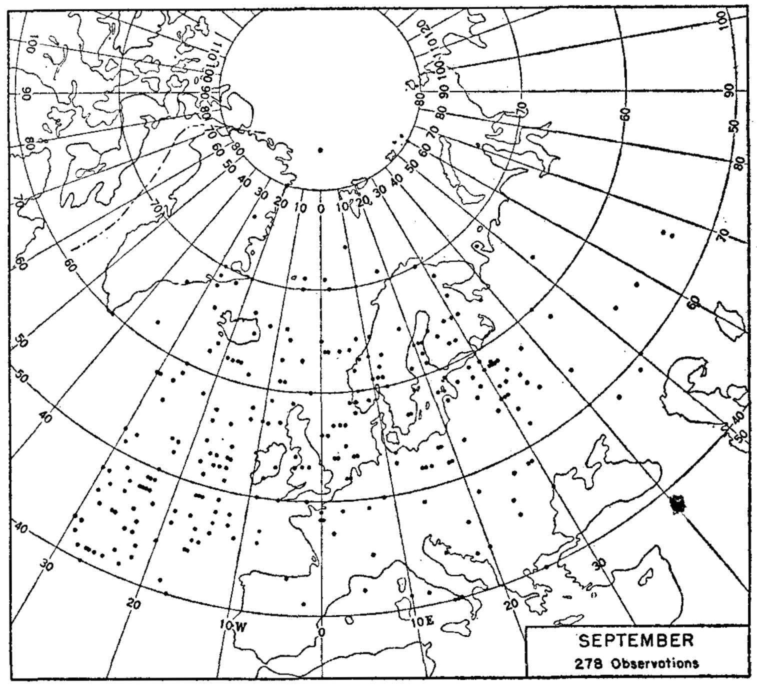

FIGURE 11.—Positions of the 278 blocking Highs observed on daily maps, September 1899–1938.

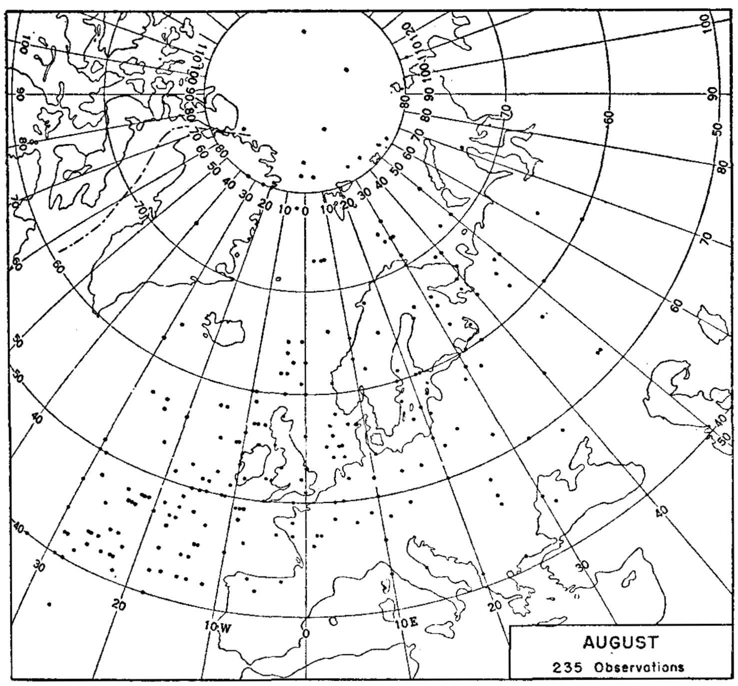

FIGURE 10.—Positions of the 235 blocking Highs observed on daily maps, August 1899–1938.

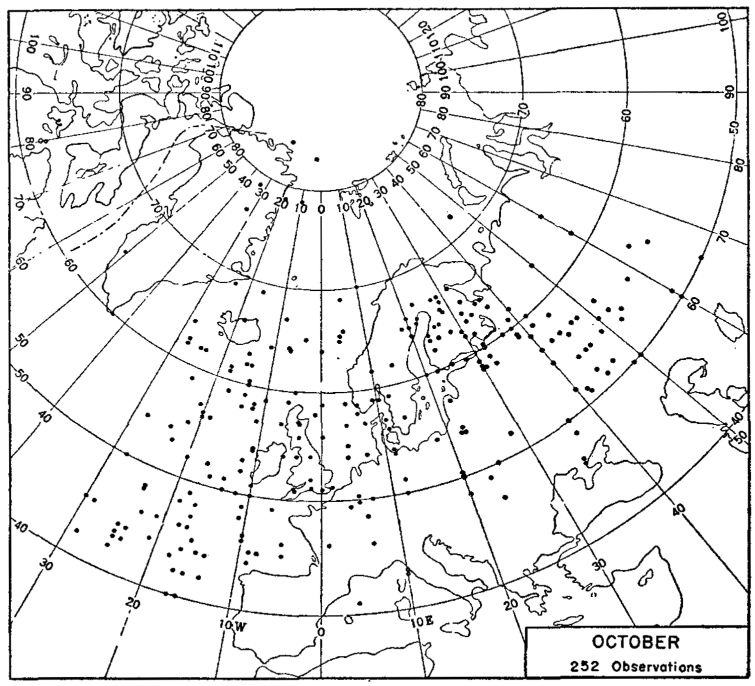

FIGURE 12.—Positions of the 252 blocking Highs observed on daily maps, October 1899–1938.

Rex [3] found that blocking reaches a maximum in April and May. His data consider about twice as many anticyclonic vortices as cyclonic; but if restricted to the anticyclonic vortices, his data show more cases of blocking in May. It is also in May that Highs stagnate over Nova Scotia and the Labrador Current. Johnson [7] has described how Highs moving across Canada from the west stagnate east of Hudson Bay when there is a warm upper level flow from the Central Plains of the United States.

June (*fig. 8*)—Blocking diminishes in June (280 cases) from the maximum in May but the positions occupy the same geographical location. There are a few less cases off Ireland and in the Norwegian Sea and a few more cases near the Azores.

July (*fig. 9*)—Aside from the overall decrease in cases (231), the most noticeable feature about July is the concentration of blocking Highs near the Azores. This is perhaps a reflection of the intensification of the Azores High at this time of year. The mean pressure at Horta,

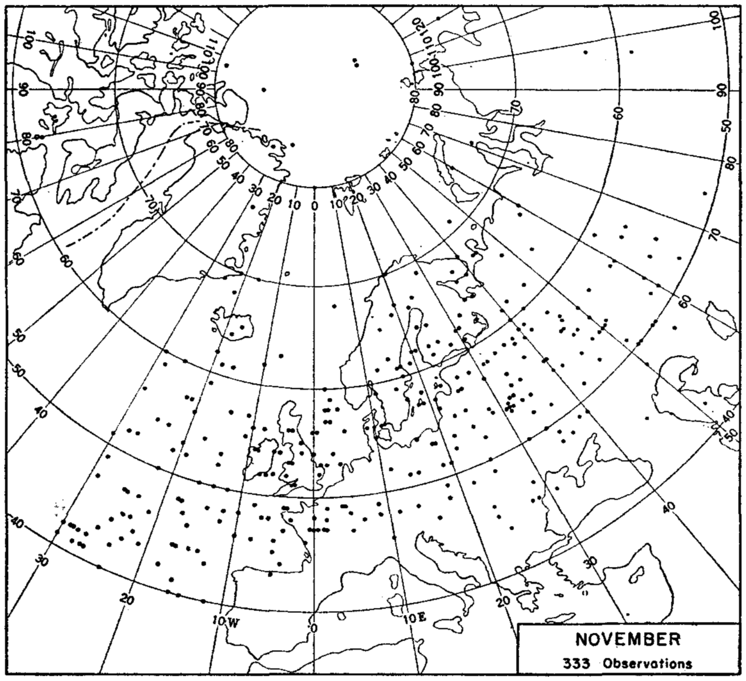

FIGURE 13.—Positions of the 333 blocking Highs observed on daily maps, November 1899–1938.

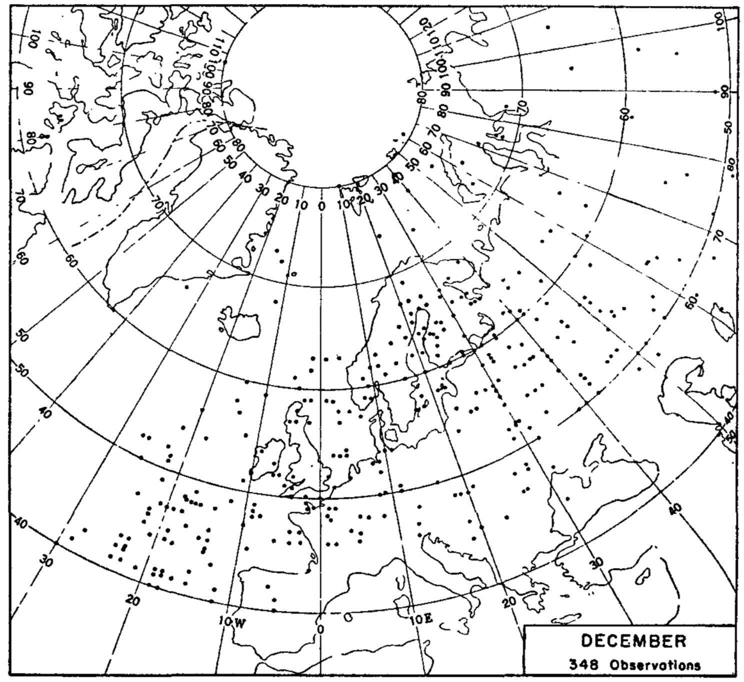

FIGURE 14.—Positions of the 348 blocking Highs observed on daily maps, December 1899–1938.

Azores, is highest in this month [8]. This tendency begins in June but becomes more pronounced in July. At the same time the mean easterly Trades over Puerto Rico, which extend to a height of 9,000 feet in April, rise to 25,000 feet in July, and at Key West, Fla., the easterlies rise from 5,000 feet to over 30,000 feet for the same period [9]. The hurricane season in the Caribbean and Gulf of Mexico is underway.

August (*fig. 10*)—In August, with 235 cases, there is still a concentration of points near the Azores but now they are removed farther northward than in July. There are scattered cases northeast of the Azores to Finland. According to Mitchell [10] and other observers, August is the first month of the hurricane season that hurricanes move across the Atlantic from the Cape Verde Islands. This suggests that by August the Azores High has moved far enough north to allow a large cyclonic circulation to exist south of the High to the Equator. An inspection of the upper-level normal charts [11] at the highest elevation, 19 km., shows that before August there is no easterly component that would allow a deep circulation to cross the Atlantic at low latitudes. An unpublished study, by the author, of tropical Lows that crossed the Atlantic from the Cape Verde Islands to the Windward Islands shows that a tropical circulation is most likely to prevail when the pressure in the Azores High is 1026 mb. or less.

September (*fig. 11*)—The Azores High block is still apparent in September but has moved northward and is centered about 46° N., 24° W. Also, there are the beginnings of blocking on the Continent, particularly in the western part of Russia, and the total number of cases has increased to 278.

October (*fig. 12*)—There are many cases by October over eastern Europe, in Finland, over the Karelian Peninsula and western Russia, but the total number has decreased to 252. The number of cases has diminished over the ocean and the concentration near the Azores is no longer dominant. The cold weather pattern is established over Europe in October when increased blocking means below normal temperatures in central and eastern Europe and temperatures above normal in Iceland. Typical years of this type are 1914, 1915, 1919, and 1936.

November (*fig. 13*)—This month brings a marked increase in blocking cases (333), particularly over continental Europe. The axis of observations definitely moves southward from the previous month.

December (*fig. 14*)—Blocking action for the year reaches a maximum in this month (348 cases). There are many cases in the ocean off France and Spain and another concentration in Russia, around the Gulf of Bothnia, in Sweden and Finland. There are a few high centers east of the Urals. In these the pressure is very high; one High was noted that reached 1070 mb. December also shows a tendency for the observations to be concentrated in a band as is the case in January. The temperature conditions over Europe are similar to those in other single winter months with a high number of blocking cases. The December months of 1899, 1902, 1933, and 1938 are good examples of frequent blocking associated with cold easterly outbreaks [8].

CONCLUSIONS

That blocking is associated with the easterly polar outbreaks of winter in Europe and the warm type Highs of the Azores or a combination of the two is the conclusion that meteorologists have held for many years. The adoption of a definition of blocking consistent with this viewpoint has permitted the use of 40 years of Historical Weather Maps to determine the frequency and geographical distribution of blocking over the eastern North Atlantic and western Europe. The data shows that there is an annual oscillation in the blocking High positions. In January they lie on a band from the Azores northeast toward Finland. By May blocking has quit the Continent and extends from the Azores northward through the Norwegian Sea. In July, August, and September there is a concentration of blocking Highs north of the Azores. In October blocking Highs become more frequent over land and by December the southwest-northeast pattern is re-established.

ACKNOWLEDGMENT

The writer wishes to acknowledge the helpful assistance of Mr. Conrad P. Mook, Research Forecaster, particularly during the preparation of this report.

REFERENCES

1. J. Namias and P. F. Clapp, "Studies of the Motion and Development of Long Waves in the Westerlies," *Journal of Meteorology*, vol. 1, Nos. 3–4, December 1944, pp. 57–77.
2. R. D. Elliott and T. B. Smith, "A Study of the Effects of Large Blocking Highs on the General Circulation in the Northern-Hemisphere Westerlies," *Journal of Meteorology*. vol. 6, No. 2, April 1949, pp. 67–85.
3. D. F. Rex, "Blocking Action in the Middle Troposphere and Its Effect upon Regional Climate," Part I, *Tellus*, vol. 2, No. 3, August 1950, pp. 196–211; Part II, *Tellus*, vol. 2, No. 4, November 1950, pp. 275-301.
4. J. Namias, "The Index Cycle and Its Role in the General Circulation," *Journal of Meteorology*, vol. 7, No. 2, April 1950, pp. 130–139.
5. C.-G. Rossby, "On the Dynamics of Certain Types of Blocking Waves," *Journal of the Chinese Geophysical Society*, vol. 2, No. I, June 1950, pp. 1–13.
6. U. S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper* No. 21, Washington, D. C., October 1952, 74 pp.
7. C. B. Johnson, "Anticyclogenesis in Eastern Canada During Spring," *Bulletin of the American Meteorological Society*, vol. 29, No. 2, February 1948, pp. 47–55.
8. H. H. Clayton, "World Weather Records, "*Smithsonian Miscellaneous Collections*, vols. 79, 90, 105, Smithsonian Institution, Washington, D. C. 1927, 1944, 1947.
9. U. S. Weather Bureau, "Weather Summary, West Indies," *Pub. No. 530*, Hydrographic Office, U. S. Navy Dept., Washington, D. C. 1947.
10. C. L. Mitchell, "West Indian Hurricanes and Other Cyclones of the North Atlantic Ocean," *Monthly Weather Review, Supplement No. 24*, Washington, D. C., 1924.
11. U. S. Weather Bureau, *Normal Weather Maps, Northern Hemisphere, Upper Level*, Washington, D. C., 1944.